# LETTER

FROM

# THE SECRETARY OF WAR,

TRANSMITTING

*A copy of the report of Maj. W. E. Merrill, Corps of Engineers, upon the radical improvement of the Ohio River from Cairo to Pittsburgh.*

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March 3, 1875.—Ordered to lie on the table and be printed.

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War Department, *March* 2, 1875.

The Secretary of War has the honor to transmit to the United States Senate copy of report from Maj. W. E. Merrill, Corps of Engineers, upon the radical improvement of the Ohio River from Cairo to Pittsburgh, being the improvement contemplated by the first subdivision of the central route indicated in the report of the Senate Select Committee on Transportation-Routes to the Seaboard.

WM. W. BELKNAP,
*Secretary of War.*

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Office of the Chief of Engineers,
*Washington, D. C., March* 1, 1875.

Sir: In further compliance with provisions of the river and harbor act of June 23, 1874, for surveys and estimates for the improvements recommended by the Senate Committee on Transportation-Routes to the Seaboard, I have the honor to transmit herewith a copy of a report from Maj. William E. Merrill, Corps of Engineers, upon the radical improvement of the Ohio River from Cairo to Pittsburgh, so as to give 6 to 7 feet of navigation at low water; being the improvement contemplated by the first subdivision of the committee's central route.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
*Brigadier-General and Chief of Engineers.*

Hon. W. W. Belknap,
*Secretary of War.*

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FIRST SUBDIVISION OF THE CENTRAL TRANSPORTATION-ROUTE.

United States Engineer Office,
*Cincinnati, Ohio, February* 25, 1875.

General: In your letter of June 30, 1874, you direct me to submit a report on the following through-transportation route recommended

for examination by the Senate Committee on Transportation, viz: "The radical improvement of the Ohio River from Cairo to Pittsburgh, so as to give 6 or 7 feet of navigation at low water." In accordance with these instructions I have the honor to submit the following report.

The subject of the radical improvement of the Ohio River has been so often discussed in official reports that it will only be necessary in this connection to give the conclusions set forth in these reports. My predecessor in charge of the improvement of the Ohio, Mr. W. Milnor Roberts, civil engineer, in his last report on the river, dated April 21, 1870, and printed as Ex. Doc. No. 72, House of Representatives, 41st Congress, 3d session, recommended the ordinary slack-water system, with the addition of what he called "freshet-chutes," to be opened and closed by the floating ponton devised by the Hon. F. R. Brunot, of Pittsburgh, generally known as Brunot's hydraulic gate. The details of these chutes he did not attempt to elaborate.

The board of engineers appointed to make a report on the radical improvement of the Ohio by hydraulic gates and movable dams, consisting of Major Weitzel and myself, submitted a report, dated January 31, 1874, (printed as Ex. Doc. No. 127, House of Representatives, 43d Congress, 1st session,) in which, after giving full descriptions of all the various apparatus in use in France, Germany, England, and India, they finally concluded that before deciding absolutely upon any method of improvement, it would be desirable to test the Brunot gate on the Monongahela.

In addition they expressed the opinion that, should this gate work satisfactorily, it might be more advantageous to use it in connection with permanent dams than to adopt the French practice of movable dams.

The board thus substantially agreed with Mr. W. Milnor Roberts.

Since that time I have continued my studies in this matter, and have finally concluded that the French system of movable dams is the best that can be adopted. I have therefore abandoned the contingent opinion which, as a member of the board, I gave in favor of permanent dams with Brunot's gate and sluice. This final opinion is given in my last annual report on the improvement of the Ohio River, printed in the report of the Chief of Engineers for 1874.

My reasons for this change are briefly as follows:

1. The Brunot gate itself may not operate satisfactorily; on this point we have no positive information, as the trial which the board recommended was not made for lack of an appropriation for this purpose. Something, however, can be learned from the test made in France of the Krantz ponton, which in many respects is similar to the Brunot ponton or gate. On this matter my information is unfortunately vague, the substance of it being that I have received private advices from a distinguished French engineer, that the Krantz system, which, as stated in the board report, was a trial on the Seine below Paris, did not work satisfactorily. It is possible, however, that the trouble may have arisen from the points in which it differs from Brunot's gates, and not from those in which the two agree; I therefore do not lay much stress on this objection.

2. The Brunot gate, if used as proposed, requires the addition of a long inclined plane above and below the gate, so as, if possible, to avoid the wave at the entrance into the pass and the waves at the foot, where connection is made with the lower pool. There seems good reason to fear that these waves might prove dangerous to coal-fleets. In any event these inclined planes must be quite costly. It is apparently im-

possible to avoid them, as the construction of the Brunot ponton is such that when the pass is open the ponton is dropped down into a chamber beneath it. The depth of this chamber must be a little more than the depth of the ponton. The bottom of this chamber cannot be much, if at all, below the bed of the river, as otherwise it might become impossible to keep it clear of sedimentary deposits. Allowing one foot of clearance below the ponton, we find that the greatest depth to which the latter can be lowered is one-half a foot less than half the vertical distance between the comb of the dam and the bed of the river. Assuming a difference of level between the two pools of 6 feet, and a depth of 6 feet at the head of the lower pool, we find that the ponton when down cannot be lower than $\frac{12}{2}-\frac{1}{2}=5\frac{1}{2}$ feet below the crest of the dam, or $6\frac{1}{2}$ feet above the bottom of the river. Assuming that the opening of the pass will not materially lower the level of the upper pool, which would be the case if, as assumed in the board report, the pass were opened in low water only long enough to let a fleet through, we would have a difference of level of 6 feet to be overcome. The inclined plane could not have a steeper slope than 1 in 100, and it would be better to give it as little as 1 foot in 200. We thus see that the lower inclined plane could not be less than from 600 to 1,200 feet in length. The length of the upper inclined plane, by which the water is gradually brought to the pass, would not be great. It should be long enough to prevent any wave at the head. Probably a base of 100 feet, with a suitable widening of the upward prolongations of the side-walls, would accomplish the purpose.

The steepest natural slopes on the Ohio are found when the river is at its lowest stage. At Horsetail, 5 miles below Pittsburgh, there is a fall of 1 foot in 461 feet; at Deadman's Island, 14 miles below, a fall of 1 foot in 513; at the Twin Islands, 85 miles below, 1 foot in 781; and at the Trap, 11 miles below, 1 foot in 800. All of these slopes are much more gentle than the gentlest suggested for the lower inclined plane of the chute.

Narrow sluices for passage through permanent dams were in general use in France prior to the invention of the present system of movable dams. In order to throw as much light as possible on this vexed question of inclined planes I have made the following translations in regard to sluices from the best French authorities on this subject. The one that follows is from Minard's "*Navigation des Rivières et des Canaux.*"

The width of sluices in the narrowest part generally exceeds that of a boat by from 15 inches to 2 feet on each side. It ought to be even greater for sluices whose side-walls are parallel, in order to facilitate the entrance of boats. [The plates show the width of a large sluice to be about 40 feet.]

Sluices have been made for a fall of from 2 to 4 feet. The latter are dangerous to navigation, and to the solidity of the works. It is necessary to wait before passing boats through until the discharge has greatly lessened the fall.

The flows of sluices are from 23 to 33 feet in length. The side-walls may be longer. It is advisable that they should not be parallel, and that the pass should widen out at each end, in order to guide the boat and to prevent it from striking violently against the walls. It is likewise advisable to terminate the side-walls by wood-work extensions which will deaden the shock.

By considering the different circumstances of the passage of boats through sluices, we can determine how to arrange the dimensions of the latter.

When a boat descends freely through a sluice, it experiences a more or less violent commotion when it strikes the gyratory counter-current which is usually found at the foot of a rapid, and in which lightly-laden boats may even remain in equilibrium, pushed from behind and held back in front.

Thus in January, 1834, a large empty abandoned boat was carried in a flood of the Corrèze on to the top of the weir of the Brives dam. It was precipitated to the foot of the cataract, where it stopped; it remained there more than 15 hours, making short movements backwards and forwards, and battering down the masonry of the dam.

Also in November, 1834, having learned from an engineer that a skiff could remain, as it were, in suspense on the rapid of Saint-Maur-sur-Marne sluice, I went there with him; we ascended the current, which flowed through the sluice, in a sail-boat, completing our trip through the sluice by having the boat hauled into the cataract; on getting there we found that the boat, whose sail was lowered, remained almost at rest, its bow in the current, and its stern supported by the wave of the counter-current. An occasional stroke of the oar kept the boat in line with the current and prevented it from moving sideways. We allowed it to remain in this position for an hour, and we had much difficulty in extricating ourselves from it.

With an instrument hurriedly made, I found that the thickness of the layer of counter-current was only about 3 inches; the variations of the current made it very difficult to make this measurement; the whirl was 13 inches in diameter.

The total fall was 14 inches; the foot of the cataract was 11 inches lower than the level of the lower pool; the velocity of the current, at the position of the boat, was at least $7\frac{1}{2}$ feet per second; the skiff, holding three persons, drew 7 inches amidships. Fig. 46 shows the course followed by a floating body thrown in above the rapid.

The counter-current at the lower ends of sluices is analogous to that which we have examined in the over-falls of weirs; but the nearness of the side-walls modifies it somewhat. This effect is more or less moderated as the fall is lessened.

When a boat already on an incline corresponding to the surface of the water meets the whirl, which is from 1 foot to $1\frac{2}{3}$ feet in height, it is checked in front and strongly pushed in the rear; the result of these opposing forces is to incline it still more, and to cause the bow to plunge. It is then desirable that the floor should be as low and as short as possible, and it is even well to make an artificial excavation at the lower end.

On the other hand, it is desirable that the side-walls should be long enough to hold the water, and to reduce the slope by lengthening it. They may therefore be prolonged beyond the floor. It then becomes indispensable to build them on piles, the principal effect of the fall being a great scouring at the foot.

In fact, the removal and replacing of the beams or needles, the hauling of a boat up through the sluice, and the waiting until the current has moderated, will necessitate the opening of the sluice for three or four hours, during which time a violent current acts on the bottom. Therefore, the prolongations of the side-walls beyond the floor are as much exposed to undermining as the piers of a bridge. It is therefore necessary, unless the bottom is of rock, to surround them with deeply-driven piles and sheeting-piles.

This tendency to scouring is very great; it would be useless to oppose it. Extensions of the floor, besides injuring boats, would, sooner or later, be carried away.

The sole of the pass is not vertically undermined in the beginning; the soil, even when it is moderately firm, is at first cut away on a very steep slope near the pass, and then on a gentler slope; so that the maximum of depth is generally found at from 25 to 40 feet from the end of the sole; but afterward the scouring action travels backward to just under the sole, in consequence of a whirl with horizontal axis, which uplifts the wooden platform with which these soles are sometimes terminated. It is in consequence of this eddy that we sometimes find that, in artificial deepenings made with a vertical fall just beyond the sole, the current has brought back a part of the excavated material and has formed a slope beginning at the lower end of the sole.

The depth of the scour, and the distance to which it extends, vary with the fall and the nature of the bottom, whose hardness finally yields in the course of time. Do we not see very hard granite rocks wasted and worn away under the natural falls of rivers? It seems, in fact, that the deepening ought to increase until, in consequence of the excavation, there will be such great masses of water to be put in motion as to use up a part of the quantity of action caused by the fall; in a word, the regimen of the cataract must become established, like that of a less rapid current.

In the *Cours de Constructions* of MM. Sgauzin and Reibell are some remarks on the sluices formerly so largely used in France before the invention of movable dams, from which I extract the following paragraphs as pertinent to the question before us:

The size of sluices is limited by the method employed in closing them, which is very variable; there are sluices varying in width from 13 to 26, and even to 43 feet, depending upon the dimensions of the boats, the violence of the floods, &c.

The width of opening of sluices for the passage of floods, and for the transit of rafts or loose logs, varies from 10 to 26 feet in sluices now existing.

Their soles are generally placed on a level with the bed of the river above the dam, and they connect with the bed below the dam by a slope. In this way sluices for discharge can also be used for the passage of boats. The bottoms of these sluices, in soils that will wash, should be protected by a sole with a guard-sole below, as has been indicated for passes always open.

The width of these passes depends on the maximum widths of the boats. * * * The sluices used for navigation have their side walls prolonged much farther down

stream, in order to guide the boats and especially to make more gentle the curvilinear slope of double curvature which connects the upper pool with the lower.

To still more lessen this slope, the sluice is opened a quarter or a half hour before the passage of boats, in either direction, although this often causes an injurious lowering of the water in the upper pool. It has been recommended that the side-walls should have unequal length down stream, in order to diminish the boils and waves which are formed where the sluice-water meets that which has fallen over the dam.

The construction of the sole of a navigable sluice is surrounded with difficulties; if it is much prolonged on a straight slope downward, there is reason to fear that the boat in its oscillations will strike it; if it is made very short, there may result serious scours at the foot when the river-bottom is not firm.

Although the sluices above described differ in many particulars from the inclined planes proposed for use in connection with the Brunot ponton, they yet are sufficiently alike to enable us to get some valuable information from the experience obtained by their use during many centuries. Navigable sluices were used on the Yonne as far back as the reign of Louis IX, (1226–1270,) as an ordinance of this king is extant forbidding the construction of anything in the bed of this river that might hinder navigation. In February, 1415, Charles VI ordered that all sluices should be 24 feet in width, which decree was re-affirmed in 1520, 1598, 1669, and 1673. In 1720 the number of dams with sluices on the Upper Yonne was 25, and on the Lower Yonne there were 10. These sluices were gradually widened and improved, but the greatest change was inaugurated in 1835, when the first Poriée needle-dam was built. By this invention the width of sluices was increased to 72 feet, thus changing them into what are now known as navigable passes. In 1860, a still further advance was made by the substitution of Chanoine wickets for needle-dams. This substitution is now complete, and represents the greatest advance thus far made in movable dams.

The Chanoine system, which this brief history shows to have been the culmination of the experience of centuries, is the one which I desire to put into operation on the Ohio.

I conclude, from the descriptions quoted above, that there might be serious trouble in the use of inclined planes from the dangerous scour likely to take place at the foot of these planes, and also from the waves and whirls which would endanger the safety of barges. The difficulties which were found on small rivers, and with small bodies of water, would probably be increased with larger rivers and wider sluices.

The only French systems that use the power of the stream for working the movable parts are the Girard, the Desfontaines, and the Krantz. None of these can be used for a pass whose sole is on a level with the bottom of the river, and in this respect they are like the Brunot system. It therefore follows, that, as far as our present knowledge extends, the use of sluices with gates that can be maneuvered rapidly, both for opening and closing, likewise necessitates the use of an inclined plane. It is proper to add that the use of inclined planes for chutes or passes in weirs is unknown in France; the three French systems mentioned above being only used on weirs to control the levels of the pools by regulating the discharge of the river at the site of the dam.

3. The use of permanent dams or weirs equipped with the Brunot gate would compel all up-stream navigation to go through the locks. Very high floods, in which it might be possible to go over the dams, occur so seldom in the upper part of the river, that they need not be considered. On the other hand, if the inclined-plane system should prove to work well, it may be possible to maintain a continuous down-stream navigation through the chute at all times. This would be a decided advantage if attainable. As it is necessary, in order to make an exact comparison between the proposed Brunot system and others, to assume a precise

case for comparison, I have taken the dam at or near McKee's Rocks, being the proposed site for the first dam on the Ohio River.

The French system requires all navigation both up and down stream to pass through the locks, when there is less than 6 feet of natural navigation, but at all other times the river is entirely unobstructed. The main question therefore is, which of the two systems will give most help to navigation?

I am constrained to believe that the towing interest would prefer to have the river kept as much as possible in its natural state, and that they would consider it hazardous to be always under the necessity of running a chute or going through the lock when descending the river. Experience has shown that for dams of 6 feet lift, such as are proposed in the Ohio, a rise of 15 feet in the natural river is required in order to give a depth of 7 feet over the combs. This depth would allow the safe passage of boats drawing 6 feet of water.

Confining ourselves for the present to the upper part of the river, where alone the actual work of construction is recommended at present, we find from the records of the Pittsburgh gauge, as kept during the 17 years between 1854 and 1871, (see report of Chief of Engineers for 1871, page 399,) that the average duration of a stage of 15 feet or more is but 10 days per annum. This is very irregularly distributed as follows:

| | Days. |
|---|---|
| January | 1.1 |
| February | 1.1 |
| March | 2.4 |
| April | 2.4 |
| May | 0.8 |
| June | 0.5 |
| July | 0 |
| August | 0 |
| September | 0.2 |
| October | 0.1 |
| November | 0.4 |
| December | 0.9 |
| Total for the year | 9.9 |

This shows that no dependence can be placed on passing over the dams. The times when such a feat is possible are so short in themselves, and they are so irregularly distributed through the year, that the assistance which navigation would receive from this source is too slight for serious consideration. We may, therefore, come to the conclusion that, in the vicinity of the head of the Ohio, the permanent-dam system would require all ascending boats to go through the locks and all descending boats to go through the chute.

On the French plan, the river is entirely open whenever there is 6 feet and over on the marks. Examining the record previously quoted, we find the following average durations of a stage of 6 feet or more:

| | Days. |
|---|---|
| January | 16.9 |
| February | 16.3 |
| March | 26.0 |
| April | 26.4 |
| May | 19.7 |
| June | 9.4 |
| July | 5.2 |
| August | 4.5 |
| September | 5.2 |
| October | 5.0 |
| November | 10.2 |
| December | 18.5 |
| Total for the year | 163.3 |

We thus find that on the French plan we will have an open river, with 6 feet or more of water for navigation, for nine-twentieths of the year. During the other eleven-twentieths, navigation in both directions must pass through the locks. Therefore I conclude that the French system would better provide for navigation on the Ohio than the system of permanent dams. The same course of investigation, however, would prove the exact opposite on small rivers, that seldom have a sufficiency of water for a natural navigation.

4. The effect of permanent dams is always to cause a shoaling above the dams. As a general rule this shoaling is insignificant in amount, and does not hinder navigation. It is equally true, however, that in rivers heavily laden with sand, such as those in the East Indies, the pools above dams always fill up even with the combs of the dams. I therefore conclude, that in the Ohio River above the falls, permanent dams would not cause any injurious shoaling, but that below the falls they probably would do so. As this shoaling always takes place in high water, these effects would not occur with movable dams, as at that stage they would be out of the way. Any small deposits that might occur while the dams were up would be swept away when they were down.

5. A great advantage of movable over permanent dams arises from the fact that the great strains on dams, and the great dangers of injury by undermining or by turning the abutments, occur during floods, at which time the movable dams have ceased to be dams. They are thus perfectly safe from the most serious source of danger to all constructions placed in the bed of a river.

These reasons, and the example of the French, who are the best authorities in the world on such subjects, have caused me to change my half-formed opinion into one decidedly in favor of movable dams.

## NAVIGABLE PASS AND WEIR.

The next question to be decided is the width of the navigable pass. I know of no serious objection to making this pass as wide as the navigation interests may desire, but as 400 feet is considered sufficient to allow a safe passage between bridge-piers, I have considered it unnecessary to give a greater width to the pass. The reasons why the whole river is not made a navigable pass are as follows: The pass-wickets are very large and heavy, and are not easy to handle. It is therefore desirable to reduce their number as much as possible. This can be done by making a part of the dam of smaller wickets on a foundation raised above the bed of the river. This method of construction likewise gives greater facilities in managing small rises, which if allowed to discharge by overflow above would raise the level of the upper pool too high, and yet are not sufficient to justify the opening of the pass. By dropping some of the weir-wickets, which are easily managed, the rise can be passed without difficulty and the wickets can readily be raised again. On the other hand, when the whole dam is down the weir partly obstructs the water-way, and may make too great a current through the pass if the latter be too narrow. The widest French passes on the Upper Seine are from 180 to 214 feet. They are generally a little more than 40 per cent. of the width of the river. At the selected site for the first dam on the Ohio the width of the river, exclusive of the area required for the lock and the abutment, is 1,200 feet. If we give the pass a width of 40 per cent. of the whole width of the river, it would be 480 feet wide. This width, however, seems greater than is necessary.

The widths of coal-tows seldom exceed 125 feet (or a front of 5 barges,) and as the width between the channel-piers of the Steubenville bridge is but 300 feet, of the Bellaire bridge but 322 feet, of the Parkersburg bridge but 350 feet, and of the Newport and Cincinnati bridge 400 feet, the last-named width seems ample for a navigable pass. In order, however, to provide against undue contraction of the water-way, the half of the weir adjacent to the navigable pass should have its sole at the level of the low-water line, the sole of the other half of the weir being at the usual level of two feet above low water. This is the method recommended by the latest French authorities for very wide rivers, and for those for which the usual width of navigable pass causes too great a velocity through the pass when the dam is down. On the highest level of the weir it will probably be very advantageous to use Desfontaines's drum-wickets, or the Brunot ponton. The question of choice between the two can, however, be left for future study, as in any event the dams cannot be built until the locks are finished. In making the estimate which accompanies this report, I have thought it best to assume that the whole dam will be composed of Chanoine wickets, as these will undoubtedly accomplish our object. If the other system should be thought better for the highest level of the weir, the estimate will still be substantially correct.

In my last annual report I only estimated for a width of navigable pass of 250 feet. Since then I have concluded, after consulting with those interested in Ohio River navigation, and studying first location for a dam, the surveys for which were then in progress, that it would be better to widen the pass to 400 feet.

## LOCK.

Experience in France on navigations similar to what is proposed for the Ohio, shows that it is greatly to the advantage of navigators for the locks to be large enough to pass ascending or descending fleets at one lockage. An average coal-fleet has ten barges, (130 by 25 feet,) one fuel-flat, (100 by 22 feet,) and one steamboat, (230 by 48 feet.) The barges could pass two abreast if the locks were 52 feet wide, three abreast if they were 78 feet, and four abreast if they were 103 feet. The first-named width, however, is too narrow for the usual packet steamboats, which require from 60 to 80 feet, and the last-named is too wide to be closed by the ordinary lock-gate. The width of lock must therefore necessarily be 78 feet in order to accommodate all classes of traffic in the best manner.

To hold such a fleet as I have described above, will necessitate an available length (from the lower side of the miter-wall of the upper gates to the recesses of the lower gates) of 628 feet. The length between hollow quoins will therefore be 634 feet, and the total length of the river-wall, from head to foot, will be 770 feet.

This length may seem excessive, but the advantage of passing a fleet at one lockage is very great, and the increase of cost is not in proportion to the length of the lock. The most expensive parts of a lock are the gates and the masonry around them, and they cost the same in all locks of the same width and lift, regardless of their length. The difference between a short and a long lock, of the same width and lift, is only the cost of the extra length of chamber-wall, and this is the cheapest masonry about the lock. The fleets on the Seine are somewhat smaller than those on the Ohio, although their larger barges have almost exactly the same dimensions as Ohio coal-barges. To pass one of these fleets at a single lockage, the lock-chambers on the Upper Seine

have a width of 40 feet, and an available length of from 591 to 615 feet.

In my last annual report, I recommended that the lock should be divided into two parts by a pair of middle gates, in order that single steamboats and small tows might be accommodated without using so large an amount of water as would be required to fill the whole lock.

After the detailed plans of the lock were prepared, I found that the extra cost of these gates, and of the additional culverts that must go with them, would not be justified by the saving in the consumption of water. The low-water discharge of the Ohio was found by Mr. Roberts, my predecessor, to be 1,600 cubic feet per second. This is sufficient to fill the whole lock in 3⅓ minutes. As the lock would not be used oftener than once in 15 minutes for single steamboats, or once in 20 minutes for fleets, we evidently have an abundance of water to spare even in the lowest stages. The leakage through the dam can be reduced as much as may be desired by the usual expedient of laying planks over the intervals between the wickets.

I have not estimated for a double lock, as I think that the large single one proposed will answer every purpose. It will be just as well adapted to the needs of commerce when several boats are moving in the same direction, but it will not be so useful when boats moving in opposite directions meet at a lock. To balance this disadvantage we have the greater facilities which it offers to large tows, and, besides, it should be borne in mind that when navigation is naturally most active the dam is down, the river is entirely open to navigation, and the lock is not needed. On the Seine it has not been found necessary to double any of the locks. The usual lift of the lock, when both pools are at their normal levels, will be 6 feet, but the walls have been calculated to resist the greatest pressures that can come on them when the lock is either full or emptied for repairs.

ESTIMATE.

*One river-lock, with lift of* 6 *feet,* 6 *feet on lower miter-sill,* 628 *feet of available length, and* 78 *feet of width in the clear.*

| | Cut-stone masonry. | Coursed rubble. | Uncoursed rubble. | Price. | Cost. |
|---|---|---|---|---|---|
| | *Cub. yds.* | *Cub. yds.* | *Cub. yds.* | | |
| River-wall, face | 2,434 | | | $15 00 | $36,510 |
| coping | 312 | | | 15 00 | 4,680 |
| backing | | | 2,470 | 6 50 | 16,055 |
| Land-wall, face | 1,172 | | | 15 00 | 17,580 |
| coping | 238 | | | 15 00 | 3,570 |
| backing | | | 2,818 | 6 50 | 18,317 |
| Miter-walls | 230 | | | 15 00 | 3,450 |
| Upper-wing wall, face | | 60 | | 8 50 | 510 |
| coping | 20 | | | 15 00 | 300 |
| backing | | | 120 | 6 50 | 780 |
| Lower-wing wall, face | | 40 | | 8 50 | 340 |
| coping | 15 | | | 15 00 | 225 |
| backing | | | 110 | 6 50 | 715 |
| Coffer-dam and pumping | | | | | 6,000 |
| Rock-excavation, 10,000 cubic yards | | | | 2 00 | 20,000 |
| Lock-gates, 4 leaves | | | | 4,000 00 | 16,000 |
| Wickets with apparatus, 20 | | | | 200 00 | 4,000 |
| Maneuvering needle-dam at head of lock | | | | 1,250 00 | 1,250 |
| House for lock and dam tenders | | | | 5,000 00 | 5,000 |
| Engineering—engineer and assistant 2 years | | | | 4,000 00 | 8,000 |
| Total | | | | | 163,282 |
| Contingencies, 10 per cent | | | | | 16,328 |
| Total for one lock on rock-foundation | | | | | 179,610 |

This estimate is $20,000 less than the rough estimate ($200,000) which I made in my last annual report. A large portion of this saving is due to the suppression of the middle gates, with their attendant culverts, and enlargement of the side-walls.

At the site selected for the first dam, the river has a rock-bed, but as we approached the left bank this bank is overlain by a layer of gravel and sand. The estimate which follows will therefore only apply to cases of similar foundations.

As stated before, the pass is closed by Chanoine wickets having 12 feet vertical height above the sill of the pass, and placed at a distance apart, measured from center to center of wicket, of 3.61 feet. These are the dimensions used at the Port-à-l'Anglais dam, and though they appear awkward when given in English feet, it has been thought best to preserve them for the present. There will be no difficulty in slightly changing them when the actual work of construction is begun. The interval between wickets is 0.33 of a foot, or 4 inches.

All the coffer-dams for which estimates are submitted are built to a height of 8 feet above the low-water line, so that they will not be submerged until there is 10 feet of water in the channel.

*Navigable pass giving an opening of 400 feet and having its sill 2 feet below low water.*

COFFER-DAM, PER RUNNING FOOT.

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| String-pieces | $35 per 1,000 feet | 85 feet | $2 98 |
| Sheeting-planks | do | 150 feet | 5 25 |
| Two-inch round-iron ties | 3 cents per pound | 210 lbs | 6 30 |
| Gravel | 50 cts. per cub. yd. | 6 yards | 3 00 |
| Labor | | | 5 00 |
| Cost of one running foot of coffer-dam | | | 22 53 |

## *Pumping, per running foot.*

To make an approximation of the cost of this service, it is necessary to make some assumptions. At the best, this expense must, from the nature of the case, be indeterminate.

We will assume that work can only be attempted during a period of five months, say from June 15 to November 15, that being the usual period of lowest water; that it will take two such seasons to complete the dam; and that the yearly depreciation of the pumping-apparatus will be 10 per cent., and its yearly repairs the same.

| | |
|---|---|
| A 10-inch centrifugal pump, with 15-horse-power steam-engine, will cost | $1,500 00 |
| A flat-boat for carrying it | 800 00 |
| Total cost of plant | 2,300 00 |
| Yearly cost of plant, depreciation, and repairs, 20 per cent | 460 00 |
| Cost of plant for two years | 920 00 |
| One engineer, ten months, at $90 per month | 900 00 |
| Two deck-hands, ten months, at $90 per month | 900 00 |
| Coal, three hundred bushels per month for ten months, at ten cents per bushel | 300 00 |
| Cost of pumping for two seasons, or for building 1,200 feet of dam | 3,020 00 |
| Cost of pumping, per running foot of dam | 2 50 |
| As this work is subject to extraordinary accidents by floods, it would be better to put it at | 3 00 |

*Foundation, per running foot.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Rock-excavation ........ per cub. yd.. | $2 00 | 4.5 yards | $9 00 |
| Cut-stone masonry ........ do ...... | 15 00 | 1.13 yards | 16 95 |
| Rubble ........ do ...... | 6 50 | 1.0 yards | 6 50 |
| Sills ........ per 1,000 feet.. | 45 00 | 34.0 feet .. | 1 57 |
| Labor ........ | ........ | ........ | 5 00 |
| Cost of one running foot of foundation ........ | ........ | ........ | 39 02 |

*Appurtenances of the sole per one wicket and per running foot.*

| Name of part. | No. | Material. | Quantity. | Price. | Cost. |
|---|---|---|---|---|---|
| Heurter and slide ........ | 1 | Wrought iron... | 480 lbs .... | 10 cts. per lb .. | $48 00 |
| Tripping-rod ........ | 1 | ......do ........ | 98 lbs .... | 10 cts. per lb .. | 9 80 |
| Guides ........ | 2 | ......do ........ | 42 lbs .... | 10 cts. per lb .. | 4 20 |
| Roller ........ | 1 | Bronze ........ | 26 lbs .... | 40 cts. per lb .. | 10 40 |
| Cost of appurtenances per wicket ........ | | | | | 72 40 |
| Cost of appurtenances per running foot ........ | | | | | 20 55 |
| Labor ........ | | | | | 5 00 |
| Total per running foot ........ | | | | | 25 55 |

*Wicket, total cost and cost per running foot.*

| Name of part. | No. | Material. | Quantity. | Price. | Cost. |
|---|---|---|---|---|---|
| Horse ........ | 1 | Wrought iron... | 450 lbs .... | 10 cts. per lb .. | $45 00 |
| Anchoring-rods ........ | 2 | ......do ........ | 133 lbs .... | 10 cts. per lb .. | 13 30 |
| Anchoring-disk ........ | 1 | Cast iron ........ | 80 lbs ... | 7 cts. per lb .. | 5 60 |
| Prop ........ | 1 | Wrought iron... | 600 lbs .... | 10 cts. per lb .. | 60 00 |
| Journal-boxes ........ | 4 | Cast iron ........ | 220 lbs .... | 7 cts. per lb .. | 14 50 |
| Bolts and nuts ........ | 30 | Wrought iron... | 330 lbs .... | 5 cts. per lb .. | 16 50 |
| Panel ........ | 1 | Lumber ........ | 409 feet ... | $50 per 1,000 ft. | 20 45 |
| Cost of wicket ........ | | | | | 175 35 |
| Cost of wicket per running foot ........ | | | | | 48 57 |

## LOW WEIR.

*Sill at level of low water.*

The coffer-dam required will be identical with the one employed for the navigable pass, consequently the same estimate will hold good in this case.

*Foundation per running foot.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Concrete ........ | $5.00 per cubic yard ........ | 0.75 cubic yard ........ | $3 75 |
| Gravel ........ | 50 per cubic yard ........ | 0.80 cubic yard ........ | 40 |
| Cut-stone ........ | 15.00 per cubic yard ........ | 1 cubic yard ........ | 15 00 |
| Boards—inner sheeting for concrete-frame. | 30.00 per 1,000 feet ........ | 12 feet ........ | 36 |
| Uprights for same ........ | 30.00 per 1,000 feet ........ | 5 feet ........ | 15 |
| Sills ........ | 45.00 per 1,000 feet ........ | 34 feet ........ | 1 57 |
| Riprap ........ | 1.60 per cubic yard ........ | 1.22 cubic yard ........ | 1 95 |
| Labor ........ | ........ | ........ | 5 00 |
| Cost of one running foot of foundation ........ | | | 28 18 |

The cost of the appurtenances of the sole and of the wickets will be five-sixths of the cost of the similar parts of the navigable pass. They will therefore be as follows:

| | |
|---|---|
| Appurtenances of the sole, per running foot ........ | $21 29 |
| Wickets, per running foot ........ | 40 47 |

HIGH WEIR.

*Sill 2 feet above low water. Coffer-dam same as for the low weir. Foundation per running foot.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Concrete | $5.00 per cubic yard | 1.25 cubic yard | $6 25 |
| Gravel | 50 per cubic yard | 2 cubic yards | 1 00 |
| Cut-stone | 15.00 per cubic yard | 1 cubic yard | 15 00 |
| Sills | 45.00 per 1,000 feet | 34 feet | 1 57 |
| Riprap | 1.60 per cubic yard | 3 cubic yards | 4 80 |
| Labor | | | 5 00 |
| Cost of one running foot of foundation | | | 33 62 |

The costs of the appurtenances of the sole and of the wickets will be two-thirds of the costs of the similar parts belonging to the navigable pass. They will therefore be:

| | |
|---|---|
| Appurtenances of the sole, per running foot | $17 03 |
| Wicket, per running foot | 32 38 |

PIERS.

As the length of a pier is the same as the width of the pass, the cost of its foundations per running foot measured in the direction of the length of the dam will be the same as the cost of the same length of foundation of the pass. The width of a pier being 11.48 feet, it will only be necessary to multiply the cost of the foundation of the pass per running foot by 11.48 to obtain the cost of the foundation of a pier.

| | |
|---|---|
| Cost of foundation of one pier 71.55×11.48 | $821 39 |
| 115.02 cubic yards of cut-stone masonry, at $15 | 1,725 30 |
| 101.56 cubic yards of rubble-masonry, at $6.50 | 660 14 |
| Maneuvering capstan for tripping-rod | 1,000 00 |
| Cost of one pier | 4,206 83 |

ABUTMENT.

The abutment is located at the shore end of the weir.

*Foundation of abutment.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Piles, 10′ long, driven | $4.20 each | 12 piles | $50 40 |
| Sheeting-piles, 10′ long, driven | 3.70 each | 125 sheeting-piles | 462 50 |
| Concrete | 5.00 per yard | 30 yards | 150 00 |
| Cost of foundation of abutment | | | 662 90 |

*Superstructure of abutment.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Cut-stone masonry | $15 per yard | 103.5 yards | $1, 552 50 |
| Concrete backing | 5 per yard | 87.17 yards | 430 85 |
| Capstan and gearing | | 1 capstan and gearing | 1, 000 00 |
| Grading bank, paving riprap, &c. | | | 5, 000 00 |
| Cost of superstructure of abutment | | | 7, 983 35 |

## SUMMARY.

Having thus determined the cost in detail of each part of the dam, we will now bring them together in order to determine the cost in the aggregate.

*Navigable pass.*

| | |
|---|---|
| Coffer-dam, per running foot | $22 53 |
| Pumping, per running foot | 3 00 |
| Foundation, per running foot | 39 02 |
| Appurtenances of the sole, per running foot | 25 55 |
| Wicket, per running foot | 48 57 |
| Total, per running foot | 138 67 |
| Cost for 400 feet of width | 55, 468 00 |

*Low weir.*

| | |
|---|---|
| Coffer-dam, per running foot | $22 53 |
| Pumping, per running foot | 3 00 |
| Foundation, per running foot | 28 18 |
| Appurtenances of the sole, per running foot | 21 29 |
| Wicket, per running foot | 40 47 |
| Total, per running foot | 115 47 |
| Cost of 400 feet of width | 46, 188 00 |

*High weir.*

| | |
|---|---|
| Coffer-dam, per running foot | $22 53 |
| Pumping, per running foot | 3 00 |
| Foundation, per running foot | 33 62 |
| Appurtenances of the sole, per running foot | 17 03 |
| Wicket, per running foot | 32 38 |
| Total, per running foot | 108 56 |
| Cost for 400 feet of width | 43, 424 00 |

*Abutment.*

| | |
|---|---|
| Foundation | $662 90 |
| Superstructure | 7, 983 35 |
| Cost of abutment | 8, 646 25 |

Gathering together the costs thus determined for each part of the dam, and neglecting quantities less than one dollar, we have the following:

| | |
|---|---|
| Navigable pass | $55, 468 |
| Pier | 4, 207 |
| Low weir | 46, 188 |
| Pier | 4, 207 |
| High weir | 43, 424 |
| Abutment | 8, 646 |
| Engineering and superintendence two years, at $6,000 | 12, 000 |
| Total | 174, 140 |
| Contingencies, 20 per cent | 34, 828 |
| Total estimate of cost of dam | 208, 968 |

I have added 20 per cent. for contingencies, because work like this, in the bed of a large river liable to sudden and high rises, is subject to injuries and accidents which cannot possibly be foreseen, nor can they be covered by an estimate except in this way.

The site selected for the first dam on the Ohio has a local peculiarity

which makes the works more costly than they would be at many other places. The profile of the river compels the location of the dam with one end abutting on Davis's Island. This necessitates the closing of the channel back of this island. This channel is 420 feet in width, and the dam must be built up to the same level as the normal pool, which is 10 feet above low water. It is proposed to build a dam of piles and coffer-work, the mass of the dam being riprap stone, paved on top, and supported by a long apron of riprap interspersed with piles.

The down-stream slope of the top of the dam will be one on three. The banks above and below the dam will be graded and paved, and will have a bank of riprap at the foot of the slope for protection against undermining. The method of construction thus indicated is in accordance with the best French methods.

DAM BEHIND DAVIS'S ISLAND.

*Cost of dam per running foot.*

| | |
|---|---|
| One row sheet-piling, 10′ long, at $4.75 per running foot, driven | $4 75 |
| 40 feet board measure caps, at $35 | 1 40 |
| 28 feet board-measure longitudinal stringers, at $35 | 98 |
| 53½ feet board-measure transverse ties, at $35 | 1 87 |
| 3 piles, driven, at $5 | 15 00 |
| 3.7 cubic yards stone-paving, at $3.50 | 12 95 |
| 12 cubic yards riprap, at $2 | 24 00 |
| 2 cubic yards gravel, at 40 cents | 80 |
| Labor | 5 00 |
| Total per running foot | 66 75 |
| Cost for dam 420 feet in length | 28,035 00 |

*Bank protection above and below dam.*

| | | |
|---|---|---|
| 400 piles, at $5 | $2,000 00 | |
| 925 cubic yards paving, at $2.50 | 2,312 50 | |
| 500 cubic yards grading bank, at 20 cents | 100 00 | |
| 200 cubic yards riprap, at $2 | 400 00 | |
| Total | | 4,812 50 |
| Total cost of dam, including bank protection | | 32,847 50 |

TOTAL COST OF DAM NO. 1, ON THE OHIO RIVER, INCLUDING ALL ACCESSORY WORK.

| | |
|---|---|
| Lock | $179,610 |
| Dam | 208,968 |
| Auxiliary dam behind Davis's Island | 32,847 |
| | 421,425 |

The estimates on a lock and dam thus far given presuppose a rock foundation. In case we should be compelled to build on gravel the preceding estimates must be increased. It then becomes imperative to give the lock an artificial bottom or floor of concrete, to found the pass and weirs on similar beds of concrete, and to guard against injurious filtrations by lines of sheet-piling.

This method of construction is expensive, but it seems to be the only one that gives thoroughly reliable results. On the Monongahela wooden floors are used, but they are frequently out of repair, and their weakness is constantly endangering the safety of the locks. The following extracts from Minard's Navigation des Rivières et des Canaux show the best foreign practice in such cases:

*Soil incompressible, but liable to scour.*

Sands, gravel, &c., found directly on the soil, and give the floors a thickness of from 2 to 6½ feet, depending upon the lift, the width of the lock, and the tenacity of the masonry; oppose subterranean filtrations by cross-walls of beton or masonry descending lower at the head and foot of the lock and under the miter-sills than the general foundations, or by carefully-driven rows of matched sheeting-piles under the whole width of the lock; make the floor thicker under the miter-sills and under the lower gate-chambers. Make an apron below the lock whose thickness decreases as it recedes from the lock, and whose total length depends on the lift and the resistance of the soil.

Sheeting-piles are very efficacious for intercepting subterranean communications. I have seen locks a hundred years old on the Picardy Canal which still worked passably, although the lock-chamber no longer had a floor, because the rows of sheeting-piles under the miter-sills were in good condition.

To have the rows of sheeting-piles well joined it is necessary to use the system which was formerly followed and which is yet in use among the Dutch.

The piles are so arranged as to be capped by two parallel stringers, leaving between them an interval equal to the thickness of the sheeting-piles; the latter can then be driven by continuous panels, and by slight successive penetrations along the whole length of the row, so that they reach their ultimate penetration without losing contact, and mutually sustaining each other; which, as is well known, is the advantage of driving by panels.

On the other hand, when they are driven by the ordinary method of first driving piles held between two rows of stringers, and then sheeting-piles in the interval between the clamps, the piles obtain isolated holds, independent in direction one of the other, and it is difficult to form a connection between them and the intermediate sheeting-piles.

Ties that are parallel to the length of a lock are the cause of dangerous filtrations, because when the earth settles which was placed under them it leaves a void which cannot be filled, and which establishes a continuous communication from the water above the lock to that below it, whilst similar voids under the caps are interrupted at each pile.

If, as often happens in these kinds of soil, the springs are very abundant, after having excavated until the pumping becomes too costly, the trench for the foundations should be finished by dredging. The bottom should be graded to suit the drainage; the sides of the excavation should be slightly raised; then drainage-wells should be dug in the lowest parts; after which the whole should be covered by a bed of from 1 to 2 feet of beton, so as to have a kind of large, flat, impermeable canal, in which pumping can be done after the mortar has set.

Beton, placed on the soil, chokes or diminishes the bottom springs, and makes pumping much less expensive. I found in a similar case that ten Archimedean screws were sufficient to lay bare an excavation covered with 16 inches of beton, while seventeen screws had not succeeded in getting water lower than 2⅓ feet above the bottom of this excavation.

If the foundations are much below the level of the springs, it will be necessary, after dredging, to drive an inclosure of piles and sheeting-piles at the feet of the main slopes of the excavation, which must be somewhat widened; then a layer of beton, of from 2 to 3 feet in thickness, must be poured into the inclosed space; next, by means of scaffolds resting on the heads of the piles of the inclosure, whose top must be above the level of the springs, vertical or inclined posts must be planted in the beton, which will serve to support panels, so as to make a second interior inclosure, forming with the first one a perimetrical coffer-work, which should be filled with beton up to the level of the springs, supporting it on the exterior by earth filling. We will thus have a coffer-dam, inside of which we can pump out after the mortar has set. The posts and panels will then be removed, and the masonry will be built. The masses of beton in the coffer dam, cut in steps if the posts were inclined, will form part of the side-walls and of the lift-wall. At the lower end of the lock they must be removed to below the surface, in order to open communication with the lock, unless from motives of economy this part of the coffer-dam was made of clay, which can more readily be removed.

If there is danger of cracking the beton by driving in the posts, their feet can be buttressed by long timbers extending from one side of the coffer-dam to the other.

The interior posts ought to be somewhat inclined; if they are much inclined, considerably less beton is required. But that part which fills the acute angle of the coffer-work can only get there by flowing down a slope, and at this part all the milk of the beton (*laitance*) will be accumulated. This has but a very moderate consistence, and may give rise to accidents, which can be avoided by using vertical or slightly-inclined panels.

I have given the above translation on account of its intrinsic value, and because it is contained in a very valuable treatise, (Minard's Navi-

gation des Rivières et des Canaux,) which is now out of print. This book was recommended to me by a distinguished French engineer, (M. Malézieux,) as the best authority on such work, and by good fortune I succeeded in securing a copy. I ought to add that "beton" and "concrete" are synonymous terms.

I think that I am perfectly safe in saying that every lock on the Ohio will be founded on rock, gravel, or sand.

Having estimated for a lock on rock foundation, it remains to determine what modification will be required in the estimates for sand and gravel foundations.

The great difficulty occurs in the lock-chamber. Although by using sheet-piling we may greatly reduce the percolation of water through the soil under the lock, it is impossible to stop it entirely. The effect of this under-current of water is to cause an upward pressure on the floor of the lock whenever the chamber is empty. This upward pressure must be met by dead-weight, or by weight aided by tenacity. If we use nothing but concrete, it will resist partly by its weight, (due allowance being made for reduction of weight by immersion,) and partly by its construction as a monolith with its ends firmly held under the side-walls.

If we fill the area with piles and a less amount of concrete in the spaces between the piles, we will then have a resistance due to the weight of the concrete in water, increased by the resistance of the piles to extraction.

Lastly, we may use masonry built in what is known as plate-bands, or reversed arches with an infinite radius for the intrados. The keystone is wedge-shaped, with its widest face lowest; the other voussoirs have their sides inclining toward the key, and their under-widths are slightly greater than their widths at the intrados. The plate-band may therefore be considered as the extreme case of a flat arch. It may be built on a foundation of concrete, or on a wooden platform, thus making two additional methods.

All the plans described above require the same expenditure for coffer-dam, and for the rows of sheet-piling designed to prevent subterranean filtration. The cost of these works will therefore be estimated before going into the details of the floor.

## COFFER-DAM.

This will be built of two rows of piles and sheeting-piles, 8 feet apart, and the space between the rows will be filled with gravel. The outside sheeting-piles will be 3 inches thick and 12 feet long; the inner ones being 2 inches by 10 feet long. The latter will the driven by hand.

*Coffer-dam per running foot.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Piles, 18′ long | $5.40 per pile driven | 1-5 | $1 08 |
| Outer sheeting-piles | 3.00 per pile driven | 1.1-5 | 3 60 |
| Inner sheeting-piles | 40.00 per 1,000 feet | 20 feet, board-measure | 80 |
| Wales | 35.00 per 1,000 feet | 12 feet, board-measure | 42 |
| Gravel | 50 per cubic yard | 2⅓ cubic yards | 1 17 |
| Labor | | | 2 00 |
| Total | | | 9 07 |
| Cost of 1,040 feet of coffer-dam | | | 9,434 80 |

*Sheeting-piles.*

The sheet-piling, to prevent filtration, should extend along the whole length of the river-wall, across the head, across the foot, under the lower miter-sill, and on the prolongation of the line of the dam. Its total length will be 1,136 feet.

*Sheet-piling per running foot.*

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Piles, 14′ long | $4.68 | 1-10 | $0 47 |
| Sheeting-piles | 4.80 per pile driven | 1.1-5 | 5 76 |
| Wales | 35.000 per 1,00 feet | 10.67 feet, board-measure | 37 |
| Labor | | | 1 00 |
| Total | | | 7 60 |
| Cost of 1,136 feet of sheeting-piles | | | 8, 633 60 |

*Pumping.*

The price of pumping will be taken at the price previously determined, viz, $3,020 for the two seasons that will probably be required for constructing the lock.

## FLOORS OF LOCK-CHAMBERS.

*Concrete only.*

To determine the necessary thickness of the concrete, De Lagrené, (Navigation Intérieure, vol. iii, p. 77,) gives the following formula:

$$e = \frac{-l^2 + l\sqrt{l^2 + 2h\pi}}{\pi}$$

in which

$e =$ thickness of concrete in meters;
$l =$ half-width of lock in meters $= 12$;
$h =$ lift of lock in meters $= 2$;
$\pi =$ safe tensile-strain on concrete $= 5$ tons per square meter.

Substituting these values in the formula, we get

$$e = \frac{-144 + 12\sqrt{144 + 2 \times 2 \times 5}}{5} = 1.9 \text{ meters} = 6\tfrac{1}{4} \text{ feet.}$$

This result is a large one, and, as experience has shown (Minard, Navigation des Rivières et des Canaux, p. 184) that the under-pressure is always less than the theoretical head, I have estimated on a uniform thickness of 6 feet.

| | |
|---|---|
| 17,333 cubic yards concrete, at $5 | $86, 665 |
| 22,000 cubic yards gravel-excavation, at 30 cents | 6, 600 |
| | 93, 265 |

*Piles and platform with concrete.*

The usual practice in France is to put the concrete on top of the platform, while the contrary is the practice in this country. It seems

to me that where concrete is used under the platform voids may occur under the bottom of the lock by settlement or otherwise, and that under these circumstances the concrete would probably become detached from the piles and the under-surface of the platform, with which its bond is necessarily weak, and would fall into these voids. If this should happen, the platform would have to withstand the under-pressure without any help from the concrete. This would not occur, however, where the concrete was placed above the platform, and for that reason I prefer the French practice.

In the following estimate the supporting-piles are placed 7 feet apart over the whole area occupied by the chamber, and 3½ feet apart under the walls, and 3 feet of concrete is placed on the platform. The maximum upward pull on each pile under the chamber, allowing for the maximum under-pressure due to the head, is calculated at 5 tons, but experience has shown that this is much greater than will be found in practice. The friction on the sides of the piles will be ample to withstand this upward pressure even at its maximum.

*Lock foundation-piles and concrete.*

| Materials. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Piles 12 feet long, driven | $425 | 2,576 | $10, 948 |
| Caps 10 by 12 | $35 per 1,000 | 135,000 | 4, 725 |
| Iron straps, spikes, and bolts | 6 cents | 70,000 pounds | 4, 200 |
| 4-inch floor-planks | $35 per 1,000 | 312,000 | 10, 920 |
| Transverse floor-binders, 6 by 8 | $35 per 1,000 | 34,320 feet b. m. | 1, 201 |
| 8-inch spikes | 4 cents | 18,000 pounds | 720 |
| Labor capping piles | 50 cents | 2,576 | 1, 288 |
| Labor laying floor | 50 cents | 780 linear feet | 390 |
| Labor laying floor-binders | $2 | 110 | 220 |
| Concrete | $5 | 8,667 cubic yards | 43, 335 |
| Rip-rap | $1.50 | 2,500 cubic yards | 3, 750 |
| Gravel-excavation | 30 cents | 22,000 cubic yards | 6, 600 |
| Filling | 50 cents | 2,500 | 1, 250 |
| Total | | | 89, 547 |

*Plate-bands of masonry resting on concrete and on piles and platform.*

The thickness of the plate-bands will be taken at 2½ feet, resting on 2 feet of concrete in the first case, and on piles and platform in the second. In the first case, therefore, there will be a substitution of 2½ feet of plate-band masonry for 4 feet of concrete. The volumes of the two will therefore be in the proportion of 5 to 8. Equality in cost would require that the price of a cubic yard of masonry should be one and three-fifths greater than that of a cubic yard of concrete. But as this masonry must be of cut-stone, it is evident that its cost would more than exceed this limit. This method of construction, therefore, need not be examined in detail. The same remarks apply still more strongly to the case of plate-bands or piles and platform, as in this case the 2½ feet of masonry only replaces 3 feet of concrete.

Where concrete is used, with or without piles and platform, the bed of concrete must extend under the side-walls, replacing a portion of the masonry. This will make a reduction in cost of about $5,000 in lock-masonry.

Summing up the results thus far obtained, we get the following:

*Lock on gravel with concrete floor.*

| | |
|---|---|
| Coffer-dam | $9, 433 |
| Sheeting-piles | 8, 634 |
| Pumping | 3, 020 |

| | | |
|---|---|---|
| Foundation and floor | | $93,265 |
| Lock, as per estimate for rock-foundation | | 179,610 |
| Total | | 293,962 |
| Deduct from estimate on rock-foundation, coffer-dam, and pumping | $6,000 | |
| Rock-excavation | 20,000 | |
| Saving on lock-walls | 5,000 | |
| | | 31,000 |
| | | 262,962 |
| Add 10 per cent. for contingencies | | 26,296 |
| Total cost of lock | | 289,258 |

*Lock on gravel with piles, platform, and concrete.*

| | |
|---|---|
| Coffer-dam | $9,433 |
| Sheeting-piles | 8,634 |
| Pumping | 3,020 |
| Foundation and floor | 89,547 |
| Lock, as per first estimate, with deductions as indicated above | 148,610 |
| | 259,244 |
| Add 10 per cent. for contingencies | 25,924 |
| Total cost of lock | 285,168 |

The foundation of concrete on piles and platform being the cheaper of the two, will be the one that will be used in the estimates.

The costs of the navigable pass, the weirs, and the piers will also be different on gravel from what they were on rock.

The following are the estimates on this part of the work:

The coffer-dams are allowed to remain and become a part of the work, care being taken to cut them down to a foot or two below the level of the sills. The high weir has practically no coffer-dam, as what might be considered such is filled with concrete, and thus made the foundation for the wickets.

*Navigable pass and low weir on gravel.*

COFFER-DAM AND FOUNDATION.

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Coffer-dam: | | | |
| Piles, 18 feet long | $5.16 per pile driven | 2-5 | $2 06 |
| Sheet-piles | $6.65 per pile driven | 2 | 13 30 |
| Stringers | $35 per 1,000 feet | 980 feet | 34 30 |
| Small sheet-piles | $1.50 per pile driven | 2 | 3 00 |
| Binders | $35 per 1,000 feet | 7 feet | 25 |
| Bolts | 3 cents per pound | 200 pounds | 6 00 |
| Dredging | 30 cents per yard | 7 yards | 2 10 |
| Concrete | $5 per yard | 5½ yards | 27 50 |
| Cut-stone | $15 per yard | 1 13-100 yard | 16 95 |
| Sills | $45 per 1,000 feet | 34 feet | 1 51 |
| Labor | | | 5 00 |
| Total per running foot | | | 111 97 |

*High weir on gravel.*

COFFER-DAM AND FOUNDATION.

| Material. | Price. | Quantity. | Cost. |
|---|---|---|---|
| Piles, 13 feet long | $4.56 per pile driven | ¾ | $3 36 |
| Sheet-piles | $5.63 per pile driven | 2 | 11 26 |
| Stringers | $35 per 1,000 feet | 80 feet | 2 80 |
| Binders | $45 per 1,000 feet | 208.8 feet | 9 40 |
| Sills | $45 per 1,000 feet | 34 feet | 1 51 |
| Concrete | $5 per yard | 3 yards | 15 00 |
| Gravel | 50 cents per yard | 2 yards | 1 00 |
| Rip-rap | $2 per yard | 1 yard | 2 00 |
| Labor | | | 5 00 |
| Total per running foot | | | 51 33 |

*Pier on gravel.*

The cost of foundation will be the same as that for the pass on gravel. The area of the pier will either be included in the coffer-dam for the pass, or in that for the low weir, and therefore its cost can be obtained from the one given for these parts by omitting the cut-stone and sills and multiplying by 11.48.

We therefore have:

| | |
|---|---|
| Foundation, (111.97—18.46) × 11.48 | $1,073 50 |
| Masonry and capstan, as per previous estimate | 3,385 44 |
| Total | 4,458 94 |

*Abutment on gravel.*

The estimate already made for the abutment supposes it to be founded on gravel, and therefore it need not be changed.

SUMMARY.

Bringing together the estimates just made, we find the following:

*Navigable pass on gravel.*

| | |
|---|---|
| Coffer-dam and foundation, per running foot | $111 97 |
| Pumping, per running foot | 3 00 |
| Appurtenances of the sole, per running foot | 25 55 |
| Wicket | 48 57 |
| Total | 189 09 |

*Low weir on gravel.*

| | |
|---|---|
| Coffer-dam and foundation, per running foot | $111 97 |
| Pumping, per running foot | 3 00 |
| Appurtenances of the sole, per running foot | 21 29 |
| Wicket | 40 47 |
| Total, per running foot | 176 73 |

*High weir on gravel.*

| | |
|---|---|
| Coffer-dam and foundation, per running foot | $51 33 |
| Pumping, per running foot | 3 00 |
| Appurtenances of the sole, per running foot | 17 03 |
| Wicket | 32 38 |
| Total, per running foot | 103 74 |
| Pier | 44 59 |
| Abutment | 86 46 |

TOTAL ESTIMATE FOR OHIO RIVER.

In making this estimate it is first necessary to have an approximate location for each lock and dam, and then to apply to the lengths thus determined the costs per running foot that are given above.

In the estimate based on rock-foundation the prices per running foot do not contain the 20 per cent. for contingencies which was subsequently added, nor is it contained in the estimates per running foot for gravel-foundations; adding this percentage to the calculated sums per running foot, we have the following general table of costs, from which we can obtain the approximate costs of all the parts of any dam, whatever may be its length. The abutment is supposed in all cases to rest on sand or gravel, as also the dams for closing island-chutes.

*Table of costs of different parts.*

| | Rock-foundation. | Gravel-foundation. |
|---|---|---|
| Lock | $179, 610 00 | $285, 168 00 |
| Navigable pass ... per foot | 166 40 | 226 91 |
| Low weir ... do | 138 56 | 212 08 |
| High weir ... do | 130 27 | 112 49 |
| Pier | 5, 049 00 | 5, 351 00 |
| Abutment | ............ | 10, 375 00 |
| Dam behind island ... per foot | ............ | 78 21 |

The following list gives the approximate locations for all the dams required on the Ohio, in order to give 6 feet of water for navigation at all times. It is not supposed that these exact sites will be chosen, because no detailed examination with a view to choosing sites was made below Wheeling, nor would it have been judicious to have expended any money on a more extended examination in advance of the actual construction of at least one movable dam. The experience which will necessarily be acquired in such construction will probably lead to some modifications in the plans herewith presented, though I am firmly of the opinion that these modifications will be improvements in details and not changes in the general plan.

It should be added that the special survey made last summer between Pittsburgh and Wheeling demonstrated that there was an error of about 8 feet in the fall between these two cities as reported in the final report of Mr. Milnor Roberts. I believe that for this part of the river Mr. Roberts used the old surveys of 1838, and the inaccuracy was probably in them. This error shows that two more dams will be required on the Ohio than he supposed. According to our present information 68 dams is all that will be needed.

*Approximate location of proposed dams on Ohio River.*

| Number. | Miles from Pittsburgh. | Locality. | Length. | | Lift of dam. |
|---|---|---|---|---|---|
| 1 | 4. 7 | Davis's Island | 1, 580+ | 420 | 6. 000 |
| 2 | 8. 0 | Duff's Bar | 1, 040+ | 450 | 5. 769 |
| 3 | 11. 3 | White s Bar below Hayes's Run | 1, 350 | | 6. 441 |
| 4 | 13. 8 | Head of Deadman's Island | 1, 550 | | 5. 940 |
| 5 | 20. 0 | 1,000 feet above Crow Island | 1, 160 | | 6. 054 |
| 6 | 26. 5 | Beaver Shoals | 1, 390 | | 6, 396 |
| 7 | 32. 8 | Foot of Montgomery's Island | 1, 425 | | 6. 770 |
| 8 | 37. 8 | Head of Georgetown Island | 1, 180 | | 5. 280 |
| 9 | 43. 0 | Foot of Babb's Island | 1, 500 | | 6. 000 |
| 10 | 54. 5 | Black's Island | 1, 000+ | 600 | 6. 000 |
| 11 | 62. 0 | Brown's Island | 700+ | 600 | 6. 000 |
| 12 | 68. 0 | Head of Wells's Bar | 1, 350 | | 6. 000 |
| 13 | 77. 5 | Beech Bottom Bar | 1, 350 | | 6. 000 |
| 14 | 89. 0 | Head of Wheeling Island | 1, 000× | 700 | 7. 000 |
| 15 | 94. 0 | Mouth of McMahon's Creek | 1, 100 | | 7. 018 |
| 16 | 102 0 | 2,000 feet below Big Grove Creek | 1, 200 | | 6. 000 |
| 17 | 112. 5 | 1,400 feet above Fish Creek | 750+ | 750 | 6. 000 |
| 18 | 119. 3 | 2,600 feet below Opossum Creek | 1, 000 | | 6. 000 |

*Approximate location of proposed dams on Ohio River*—Continued.

| Number. | Miles from Pittsburgh. | Locality. | Length. | Lift of dam. |
|---|---|---|---|---|
| 19 | 127.3 | 500 feet below Fishing Creek | 1,350 | 6.000 |
| 20 | 138.4 | Middle of Wells's Island | 1,000+ 800 | 6.000 |
| 21 | 146.7 | Head of Petticoat Bar | 1,380 | 6.000 |
| 22 | 158.8 | 1,400 feet below Middle Brother | 1,600 | 6.000 |
| 23 | 170.0 | 2,400 feet below Duck Creek | 600+ 950 | 6.000 |
| 24 | 180.4 | Head bar of Cole's Island | 2,300 | 6.000 |
| 25 | 188.4 | Foot of Blennerhassett's Island | 1,650 | 6.000 |
| 26 | 202.2 | Head of Belleville Bar | 1,100+ 750 | 6.000 |
| 27 | 212.3 | 1,600 feet above Swan Bar | 1,600 | 6.000 |
| 28 | 223.0 | Head Old Town Bar | 1,400 | 6.000 |
| 29 | 233.0 | 600 feet below Upper Letart's Island | 850+ 450 | 6.000 |
| 30 | 239.8 | Lower end of Wolf's Bar | 1,380 | 6.000 |
| 31 | 243.7 | 3,700 feet below Big Broad Run | 1,050 | 6.000 |
| 32 | 256.0 | Lower point of 8-Mile Island | 1,300 | 6.000 |
| 33 | 267.0 | Lower Point of Gallipolis Island | 1,600 | 6.000 |
| 34 | 285.3 | 460 feet above mouth of Pond Cut | 1,400 | 6.000 |
| 35 | 289.1 | Dogham Bar | 1,450 | 6.000 |
| 36 | 308.3 | Buffalo Creek Bar | 1,350 | 6.000 |
| 37 | 315.8 | Big Sandy Shoals | 1,300 | 6.000 |
| 38 | 329.4 | Ferguson's Bar | 1,500 | 6.000 |
| 39 | 336.3 | Jenalt's Shoals | 1,500 | 6.000 |
| 40 | 351.3 | Cub Creek Bar | 1,150 | 6.000 |
| 41 | 364.5 | Conoconneque Bar | 1,750 | 6.000 |
| 42 | 382.0 | Graham's Lower Station Bar | 1,850 | 6.000 |
| 43 | 393.8 | Upper end of Manchester | 1,830 | 6.000 |
| 44 | 419.0 | Lower end of Straight Creek Bar | 1,800 | 6.000 |
| 45 | 444.5 | Richmond Bar | 1,850 | 6.000 |
| 46 | 458.0 | Four-mile Bar | 1,700 | 6.000 |
| 47 | 485.6 | Foot of Medoc Bar | 1,670 | 6.000 |
| 48 | 501.3 | Rising Sun Bar | 1,950 | 6.000 |
| 49 | 509.5 | Gunpowder Bar | 2,000 | 6.000 |
| 50 | 530.8 | Head Bar of Vevay Island | 2,350 | 6.000 |
| 51 | 544.5 | Locust Creek Bar | 1,870 | 6.000 |
| 52 | 580.8 | Grassy Flats | 2,700 | 6.000 |
| 53 | 617.2 | Christopher's Crossing | 1,630 | 6.000 |
| 54 | 634.2 | Moman's Bar | 2,000 | 6.000 |
| 55 | 655.6 | Foot of Upper Blue River Island | 2,250 | 6.000 |
| 56 | 683.4 | Lower point of Flint Island | 2,800 | 6.000 |
| 57 | 709.3 | Head of Hog's Point Bar | 2,100 | 6.000 |
| 58 | 731.2 | Foot of Anderson's Bar | 2,700 | 6.000 |
| 59 | 752.3 | Little Hurricane Island | 2,550 | 6.000 |
| 60 | 767.7 | Scuffletown Bar | 3,250 | 6.000 |
| 61 | 796.4 | Henderson's Island | 2,250+ 650 | 6.000 |
| 62 | 813.3 | Head of Walnut Bend | 3,550 | 6.000 |
| 63 | 838.2 | 580 feet above mouth of Wabash River | 1,700+1,350 | 6.000 |
| 64 | 859.5 | Battery Rock towhead | 3,250 | 6.000 |
| 65 | 873.7 | Head of Hurricane Island | 2,300+1,370 | 6.000 |
| 66 | 907.5 | Cumberland Island | 2,800+1,000 | 6.000 |
| 67 | 942.5 | Head of Grand chain | 5,000 | 6.000 |
| 68 | 960.0 | Just above mouth of Cache River | 4,000 | 4.000 |

| | |
|---|---|
| Sum of widths of main river | 118,885 |
| Sum of widths of island chute | 10,840 |

I have had the above table prepared, not with the expectation that the sites selected will actually be chosen, but because such a table will undoubtedly give a sum of lengths of dam that cannot be greatly in error; and, therefore, it will represent the total length of dam required much better than can be obtained by multiplying the number of dams by any arbitrarily assumed averages, unless that average be determined from such a table.

It is impossible at present to tell how many of these locks and dams will rest on rock. I think, however, it will be safe for this general estimate to assume that twelve locks, eight navigable passes, six low weirs, and three high weirs will be on rock, and the remainder on gravel. Rock can be found on many shores for the establishment of the lock; and sometimes this rock can be found half-way or more across the river. It is very rare, however, to find it extending across the entire river with-

ing so covered with gravel as to make it better not to carry the down to it.

width of 400 feet in the clear will be given to each navigable s, and to each low weir. The width occupied by high weir will estimated at the entire width of the river, diminished by the space occupied by the lock, (assumed at 50 feet, on the supposition that part of the rock will be in the bank,) by the width of the two weirs, and by the widths of the two piers. The width of high weir will, therefore, be the width of the river, diminished by 878 feet. The sum of all the widths of river at the selected sites being 118,885 feet, the sum of the widths of high weir will be 118,885 – 873 × 68 = 59,521 feet; dividing this by 68, we find the average length of each high weir to be 875 feet. Bearing in mind that the high weirs on rock will only be found, if at all, in the upper part of the river, it will be safer to give these three high weirs an average width of 600 feet, thus making the average width of the 65 on gravel 888 feet.

FINAL ESTIMATE.

| | |
|---|---|
| 12 locks on rock, at $179,610 | $2,155,320 |
| 56 locks on gravel, at $285,168 | 15,969,408 |
| 8 navigable passes on rock, at $166.40 × 400 | 532,480 |
| 60 navigable passes on gravel, at $226.91 × 400 | 5,445,840 |
| 6 low weirs on rock, at $138.56 × 400 | 332,544 |
| 62 low weirs on gravel, at $212.08 × 400 | 5,259,584 |
| 3 high weirs on rock, at $130.27 × 600 | 234,486 |
| 65 high weirs on gravel, at 112.49 × 888 | 6,492,923 |
| 23 piers on rock, at $5,049 | 116,127 |
| 113 piers on gravel, at $5,351 | 604,663 |
| 68 abutments on gravel, at $10,375 | 705,500 |
| 70,840 lineal feet of dam across island-chutes, at $78.21 | 847,796 |
| Total cost of radical improvement of the Ohio | 38,696,671 |

The above estimate has been made with a great deal of care, and is about the best that it is possible under our present knowledge. It is a very difficult and uncertain task to make estimates for works of such magnitude in the absence of practical experience in construction of a single one, and I would not presume to undertake it at the present time, were it not for positive orders to do so. Considering the additional difficulties that will be encountered below the falls of the Ohio, on account of the short and uncertain season for work, and the enormous masses of sand that are transported by the current, which will undoubtedly cause delays and extra work, I think it would be safer to put the whole estimate at $40,000,000, which is at the rate of $41,365 per mile, the total length of the Ohio River being 967 miles. Bearing in mind the enormous tonnage that would be borne on the river, if it were made navigable throughout the year, it does not seem unreasonable to request appropriations for its improvement at least equal to the sum that would be required to build a railroad of equal length.

Poor's Railroad Manual for 1873–'74 gives the following as the average cost per mile of the railroads in the United States, deduced from the sum of the stock and bonds of the companies owning them:

| | Per mile. |
|---|---|
| New England States | $50,418 |
| Middle States | 79,427 |
| Western States | 50,550 |

These numbers include rolling-stock and expenses of all kinds.

In making appropriations for the radical improvement of the Ohio, it should be borne in mind that the radical improvement should commence at the upper end of the river, and that it would be unjust to the commerce of the remainder of the river to entirely neglect it while work

was progressing at the upper end. To remove obstructions, do nec dredging, keep up the central office, and build the dikes requir the temporary improvement of the remainder of the river, would req about $200,000 per annum, gradually decreasing to $50,000 after works were completed. This last sum, unless raised from tolls, would b perpetually required for the maintenance of the central office in charge of the works, the snag-boat for removing snags, and the two dredges, for which occupation would always be found in keeping the locks and passes clear of deposits and in improving the river for navigation when the dams were down.

To give some idea of how much money would be required to secure the radical improvement of the Ohio, and of the time necessary to construct the works, I have prepared the following table, based on the suppositions that the river below the dams will not be neglected, and that the tolls charged on the finished works will meet their own expenses for repairs and attendance. To construct one lock will probably require two seasons, and to construct one dam will require two seasons more. There is nothing, however, to prevent simultaneous work at all the sites selected; and, in fact, this would be the better method, in order to reduce to a minimum the disturbance to navigation.

I assume that whenever a part of the river is being prepared for locks and dams, that in this portion no part of the $150,000 allowed for gradually decreasing improvements by dikes, dredging, and other temporary works, will be required. In other words, if half the dams are under contract, there will only be required for misellaneous expenditures, outside of the system of locks and dams, $\$50,000 + \frac{\$150,000}{2} = \$125,000.$

The upper half of the river contains more dams than the lower half; but I have neglected this consideration, believing that it would be an unnecessary refinement.

| Time for completion. | Annual appropriations. | | | | Grand total. |
|---|---|---|---|---|---|
| | For locks and dams. | For snagging. | For dredging, &c. | Total in each year. | |
| Four years | $10,000,000 | 1st 4 years | 50,000 | $10,050,000 | $40,200,000 |
| Eight years | 5,000,000 | 1st 4 years | 125,000 | 5,125,000 | 40,700,000 |
| | | 2d 4 years | 50,000 | 5,050,000 | |
| Sixteen years | 2,500,000 | 1st 4 years | 162,500 | 2,662,500 | 41,700,000 |
| | | 2d 4 years | 125,000 | 2,625,000 | |
| | | 3d 4 years | 87,500 | 2,587,500 | |
| | | 4th 4 years | 50,000 | 2,550,000 | |
| Thirty-two years | 1,250,000 | 1st 4 years | 181,250 | 1,431,250 | 43,700,000 |
| | | 2d 4 years | 162,500 | 1,412,500 | |
| | | 3d 4 years | 143,750 | 1,393,750 | |
| | | 4th 4 years | 125,000 | 1,375,000 | |
| | | 5th 4 years | 106,250 | 1,356,250 | |
| | | 6th 4 years | 87,500 | 1,337,500 | |
| | | 7th 4 years | 68,750 | 1,318,750 | |
| | | 8th 4 years | 50,000 | 1,300,000 | |
| Sixty-four years | 625,000 | 1st 4 years | 190,625 | 815,625 | 47,700,000 |
| | | 2d 4 years | 181,250 | 806,250 | |
| | | 3d 4 years | 171,875 | 796,875 | |
| | | 4th 4 years | 162,500 | 787,500 | |
| | | 5th 4 years | 153,125 | 778,125 | |
| | | 6th 4 years | 143,750 | 768,750 | |
| | | 7th 4 years | 134,375 | 759,375 | |
| | | 8th 4 years | 125,000 | 750,000 | |
| | | 9th 4 years | 115,625 | 740,625 | |
| | | 10th 4 years | 160,250 | 731,250 | |
| | | 11th 4 years | 96,875 | 728,875 | |
| | | 12th 4 years | 87,500 | 712,500 | |
| | | 13th 4 years | 78,125 | 703,125 | |
| | | 14th 4 years | 68,750 | 693,750 | |
| | | 15th 4 years | 59,375 | 684,375 | |
| | | 16th 4 years | 50,000 | 675,000 | |

In conclusion I would add that I am not at all assured in my own mind that the system proposed will be found serviceable on the Ohio below the falls. But I do feel sure that it is a better system than that of permanent dams; and besides, it is the only other system that promises the depth required by the Senate Committee on Transportation. The system of dikes for controlling and guiding the current cannot be depended upon to give more than 4 feet at dead low water, and even this depth will require an immense development of these works.

However, if the system of movable dams is commenced at Pittsburgh, and gradually brought down the river, we will pass by degrees from hard bottom to soft sand, and while so doing we will acquire abundant experience as to the practicability of successfully encountering the shifting sands of the lower river.

It may be interesting in this connection to state that in France, between 1821 and 1853, the government spent 535 millions of francs, equal to 107 millions of dollars, in improving navigation, partly by canals and partly by rivers; during the same time private companies spent 100 millions of francs, or 20 millions of dollars, for the same purpose. I have no statistics on this subject since 1853, but the additional sum expended must be very large, as several canals have been built, and also all the larger movable dams in the Seine, Marne, and other rivers. These facts are well worth consideration, in view of the extraordinary resources recently displayed by France in bearing the burdens imposed by the disastrous war with Germany.

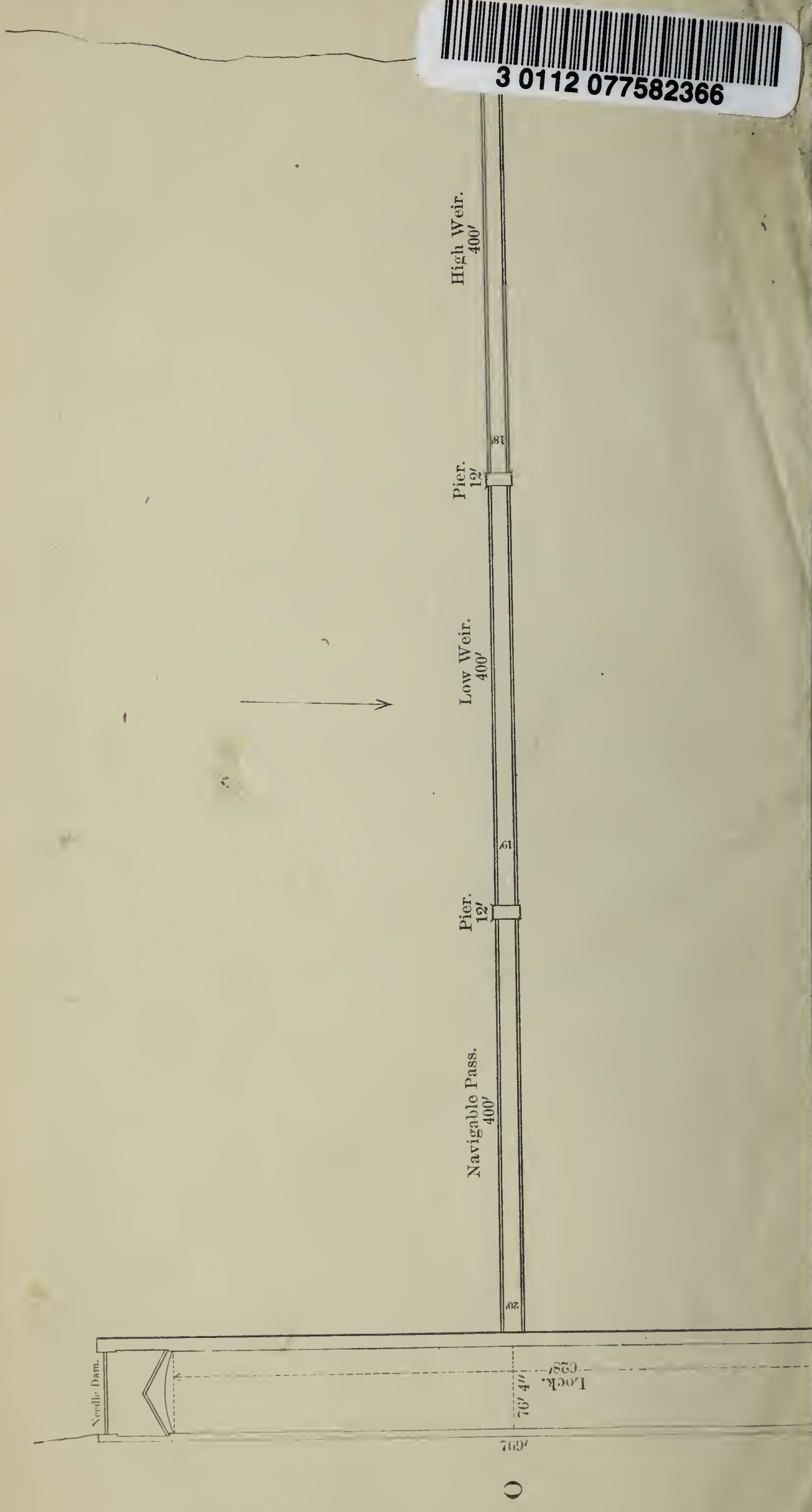
I inclose herewith a small drawing showing the proposed arrangement of lock and dam for the Ohio. I do not inclose drawings of the Chanoine wicket, as they accompanied my last annual report, although it is proper to add that I do not propose the use of the movable bridge shown in these drawings, but expect to work the wickets by a maneuvering boat.

I have been greatly indebted, in the labor of preparing this report, to the assistance of Lieut. F. A. Mahan, Engineers, who made the estimates on movable dams, and to Mr. W. Weston, assistant engineer, who made the estimates on the locks and on the dams for closing island-chutes.

Respectfully submitted.

WM. E. MERRILL,
*Major of Engineers.*

Brig. Gen. A. A. HUMPHREYS,
*Chief of Engineers U. S. A.*


High Weir.
400′
18′
Pier.
12′
Low Weir.
400′
19′
Pier.
12′
Navigable Pass.
400′
20′
Needle Dam.
Lock.
628′
76′ 4″
769′